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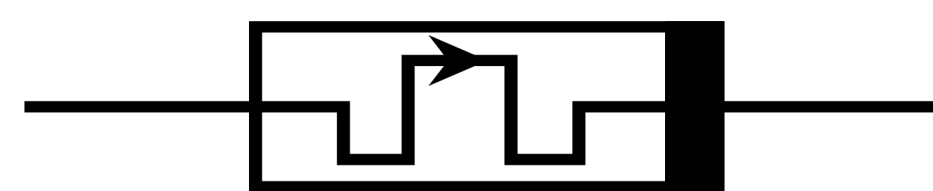
Learning to approximate functions using niobium doped strontium titanate memristors

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Introduction

- Memristors are a novel fundamental two-terminal circuit element whose resistance value depends both on the past state of the device and on the input current.
- This change in resistance resembles the potentiation and depression of synapses in the brain.
- There is strong research interest in integrating memristors into neuromorphic machine learning models.

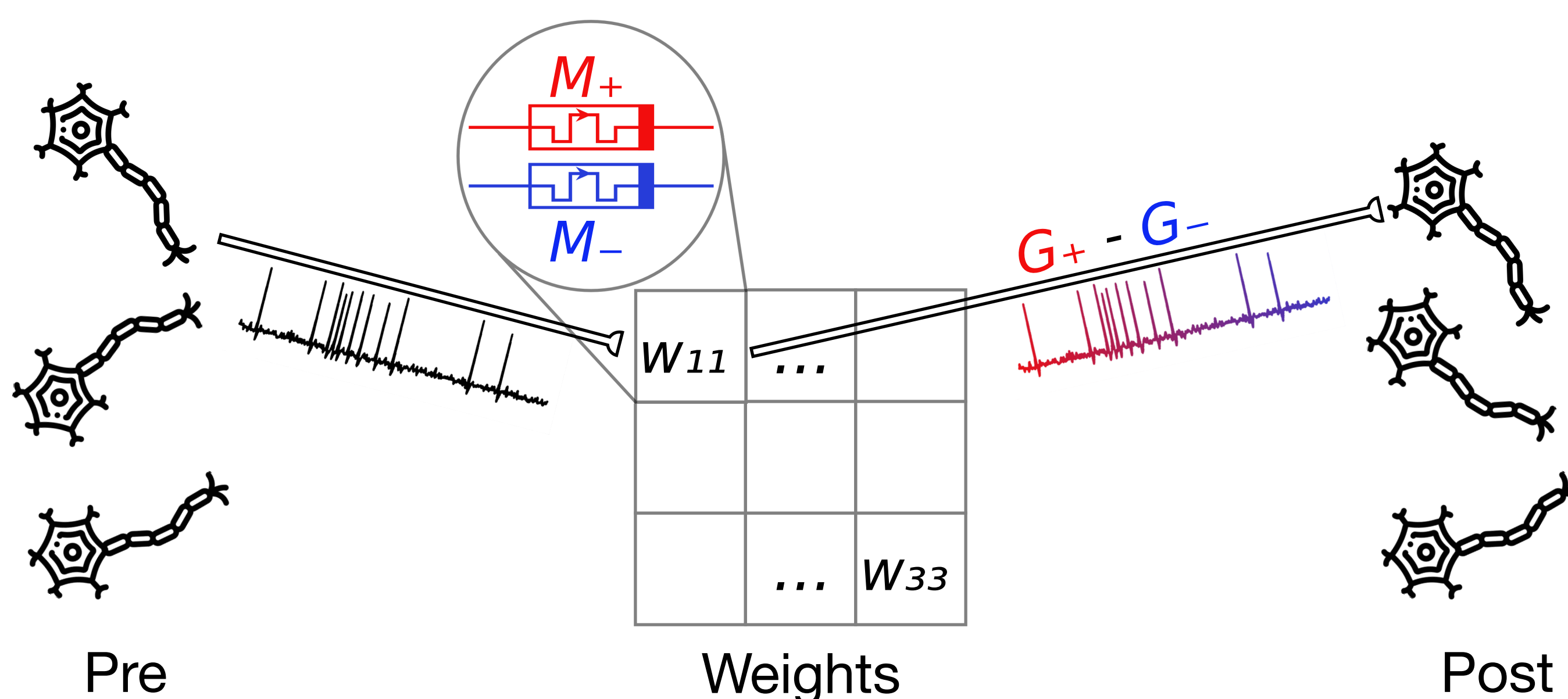


The Question

- Can we build a model that uses a particular niobium doped strontium titanate (SrTiO_3) memristor¹ to support learning multidimensional functions and their transformations?

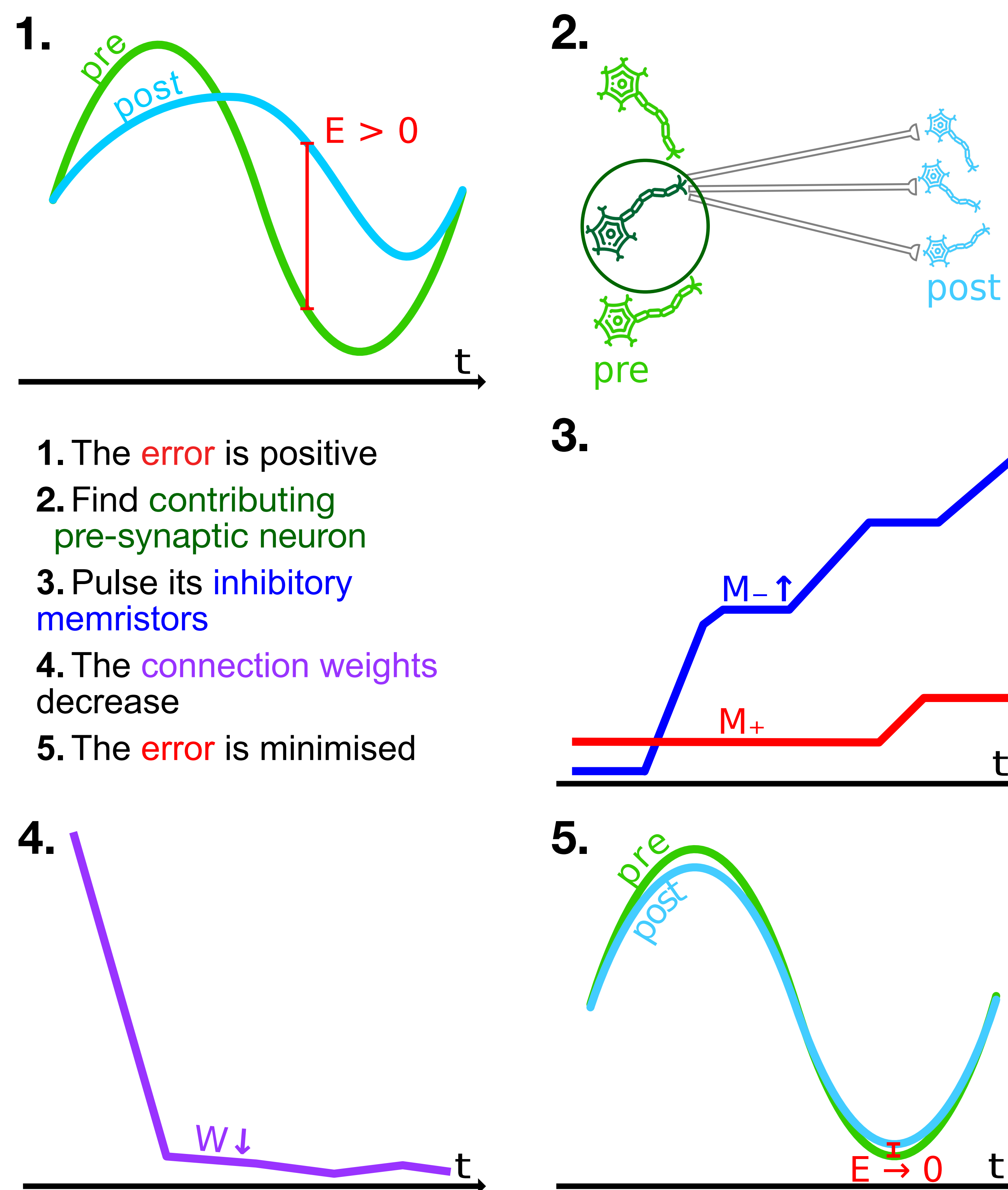
The model

- The model is built using the Nengo Brain Maker package.
- Each artificial synapse is composed of a “positive” and a “negative” simulated SrTiO_3 memristor.
- The weight of the connection is given by the difference in the normalised conductances of the two paired memristors.
- The initial state of the memristive devices is unknown as is the result of each update, through the addition of 15% noise.



The learning rules

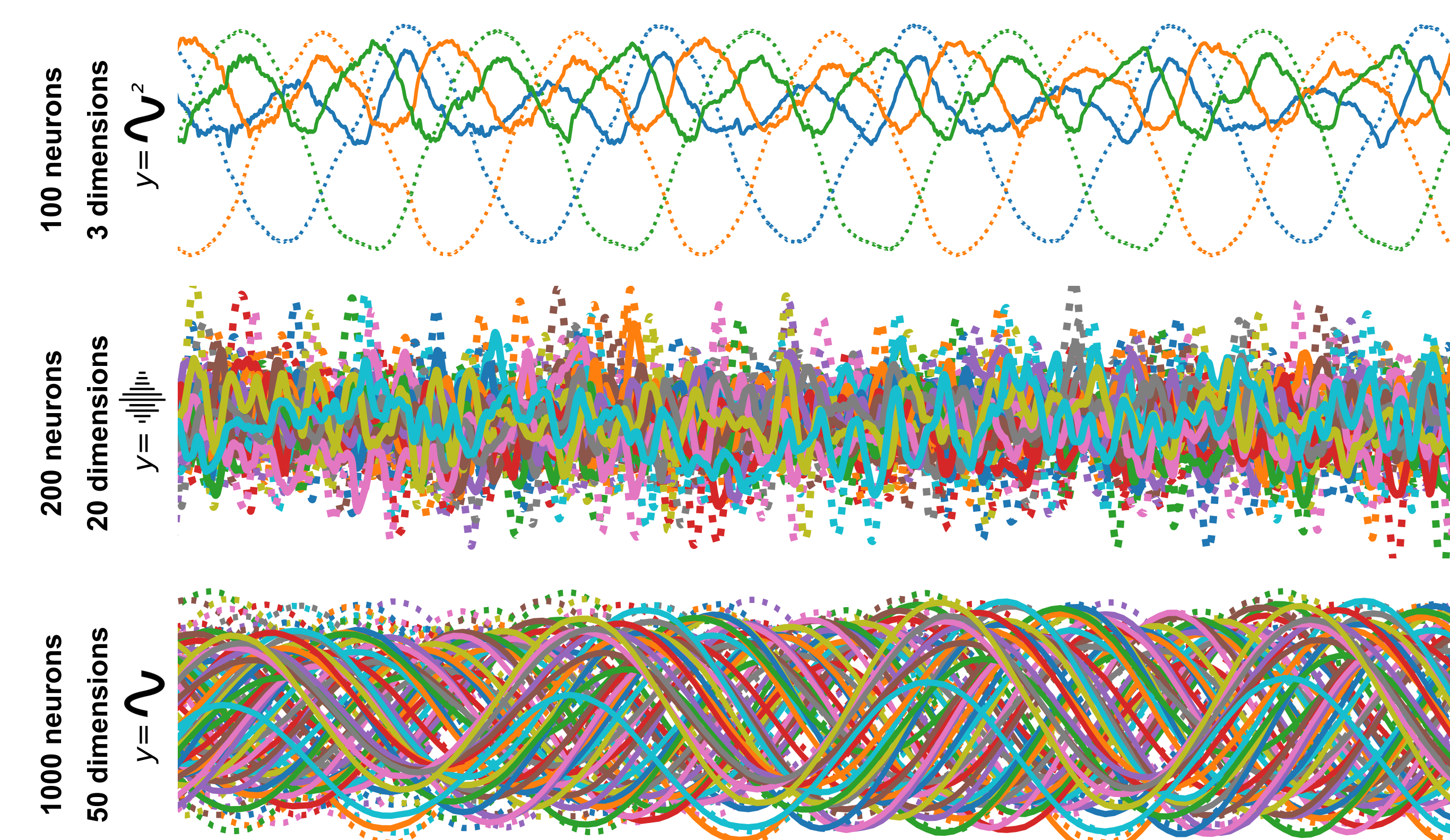
- Existing supervised and unsupervised learning algorithms (PES², BCM and Oja) are adapted in order to modulate the memristor resistance (only results for PES are shown).
- At each timestep, discrete voltage pulses are applied to one of the memristors in each pair in order to increase its conductance.
- This iterative process minimises the error between the pre- and post-synaptic neuronal ensembles' representations of the original signal.



The experiments

- We simulate 30 seconds of neuronal activity in response to a multidimensional input signal.
- Three-quarters of the time is dedicated to learning and the last eight seconds to testing the discovered weights.
- The pre-synaptic neuronal ensemble is fed either a band-limited white noise signal (|||) or a set of uniformly phase-shifted sine waves (~).
- The post-synaptic ensemble is trying to either represent the same signal as the pre-synaptic ensemble or the square.

Results



Conclusions

- The training yields a set of memristor conductances that, used as weights, enable the post-synaptic ensemble to represent functions of the pre-synaptic signal.
- These weights are found using only discrete updates and local knowledge.
- The results hold for both periodic and random high-dimensional input signals, if the neuronal ensembles are large enough to have sufficient representational power.
- The learning is robust to the presence of hardware noise and device-to-device variation.

References

- ¹Goossens et al., 2018, *Journal of Applied Physics* 124
- ²MacNeil, Eliasmith, 2011, *PLoS One* 6(9)

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More information

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Download the code: bit.ly/3egJeXm

